

“Approaches to Improving Transmon Qubits”

R&D Status Report

Reporting Period: (November 15, 2009 to December 15, 2009)

Prepared by

Bryan Jacobs, Program Manager
Johns Hopkins University Applied Physics Laboratory
The Milton S. Eisenhower Research Center
11100 Johns Hopkins Road
Laurel, MD 20723-6099
240-228-8575

Sponsored by

*Defense Advanced Research Projects Agency
Microsystems Technology Office/MTO*

ARPA Order No. X898/26, Program Code: 9D10

Issued by DARPA/CMO

Under

*Contract No. HR0011-06-D-003-0060
(Delivery Order/Call No. 0060)*

Distribution unlimited. Fundamental research exempt from prepublication controls.

DISCLAIMER

“The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Defense Advanced Research Projects Agency, the U.S. Army, or the U.S. Government.”

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE Approaches to Improving Transmom Qubits				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Johns Hopkins University Applied Physics Laboratory, The Milton S. Eisenhower Research Center, 11100 Johns Hopkins Road, Laurel, MD, 20723-6099				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 7	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Report Distribution

(a) *DARPAICMO*

Attn: Patricia S. Matyskiela, Contracting Officer
3701 North Fairfax Drive
Arlington, VA 22203-1714
Phone: (571) 218-4686
FAX: (703) 465-1075
Email: ~atricia.matyskiela@darpa.mil
(one copy each report)

(b) *DARPAIMTO*

Attn: Dr. Jagdeep Shah, Program Manager
3701 North Fairfax Drive
Arlington, VA 22203-1714
Phone: (703) 696-2253
FAX: 703-696-2206
Email: jshah((4darpa.mil
(one copy each report)

(c) *DARPAISTO*

Attn: Patrick Bailey, Assistant Director for Program Management
3701 North Fairfax Drive
Arlington, VA 22203-1714
Phone: (703) 696-5277
FAX: (703) 807-0968
Email: patrick.baileyCil{darpa.mil
(one copy each report)

(d) *DARPAISTO*

Attn: Karen McMullen, Program Analyst
3701 N. Fairfax Drive
Arlington, VA 22203-1714
Phone: (703) 696-2344
Fax: (703) 741-0638
Email: karen.mcmullen(cu.darpa.mil
(one copy each report)

(e) *DCMAIMaryiand*

Attn: Cathy Obrien, ACO
217 E. Redwood Street
Suite 1800
HROOII-06-D-0003
0060
Page 15 of 20'
Baltimore, MD 21202-3375
Phone: (410) 962-9580
FAX: (410) 962-3405
Email: Cathy.OBrien-Armacost@dcma.mil
(one copy each report)

(f) DARPA/Library
3701 North Fairfax Drive
Arlington, VA 22203-1714
Email: library(ii)darpa.mil
(One copy of the Final Technical Report)

(g) Defense Technical Information Center
(1) Email: TR(ii)dtic.mil
OR
(2) Attn: DTIC-BCS
8725 John J. Kingman Road, Suite 0944
Fort Belvoir, VA 22060-0944
(two hard copies of the Final Technical Report if unclassified)

Approaches to Improving Transmon Qubits

Monthly Progress Report

November 15 – December 15, 2009

Progress

- 1) We have completed fabrication at JHU/APL of a variety of microwave resonator cavities. The devices have been diced and are ready for use. We have:
 - a. Sapphire substrate, aluminum lift-off
 - b. Sapphire substrate, niobium lift-off
 - c. <110> silicon substrate, aluminum lift-off
 - d. <110> silicon substrate, niobium lift-off
- 2) The machine shop finished fabrication of our specially-designed evaporator jig to allow double-angle evaporation (to form the transmon with a single e-beam step).
- 3) We have made arrangements to use an e-beam lithography system on the JHU campus and one of us has finished training on the machine. We are now allowed full access to the system.
- 4) We have completed simulations of the trench shunt capacitors and have started the design process for the first round of fabrication.
- 5) We have received the quartz substrates and thus can start the trench etching process.

Planned activities

- 1) Complete Princeton subcontract – we have now enumerated all contractual issues and hope to resolve them shortly.
- 2) Ship a selection of microwave resonator cavities to Princeton for measurement of Q values.
- 3) If Q values of resonators are sufficient, start e-beam lithography of transmons at both Princeton and JHU.
- 4) Fabrication resonator cavities in aluminum and niobium on quartz substrates.

Major Expenditures

None

Changes in key personnel

None

Meetings/trip reports

None this period

Problems

- 1) It is taking much longer than anticipated to work out the subcontract with Princeton, as they took exception to some of JHU/APL's standard contractual provisions. Contracting officers from both institutions are actively involved and we anticipate that we will resolve these issues shortly.
- 2) The instrument we planned to use to measure femtofarad capacitances is broken and it may not be possible to repair. We are actively pursuing other options.

Related accomplishments

None

Fiscal status

No issues – financial data for November 2009 is presented on the following page.

R&D Status Report
Program Financial Status – November 2009

Work Breakdown Structure or Task Element	Planned Expend	Actual Expend	% Budget Complete	At Completion	Latest Revised Estimate	Remarks
Phase 1	50,020	30,643	10.2%	299,992	299,992	
Phase 2				91,793	91,793	
Subtotal						
Management reserve:						
Or Unallocated Resources:						
Total:	50,020	30,643	10.2%	391,785	391,785	

	Is current funding sufficient for the current fiscal year (FY)? (Explain in narrative if "NO")
	NO. Current funding is sufficient to cover estimated costs through June 2010, or Phase 1 of the program. We will need Phase 2 funding by the end of June 2010 to work after that date.
	What is the next FY funding requirement at current anticipated levels?
	We anticipate receiving an additional \$91,793 for Phase 2 of the program on or before June 2010.

	Have you included in the report narrative any explanation of the above data and are they cross-referenced?
	YES